TAWS – Visual Slant Range Detection Assessment

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MR3570
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1. Introduction

In an endless evolution within the Air Force Weather (AFW) community, the way meteorologists provide weather inputs to the war fighter is constantly being updated, manipulated and transformed by operational needs and technological advances. An integral part in the advancement of weather presentation is the use of a system called Target Acquisition Weapons Software (TAWS). TAWS is a weather impact tactical decision aid that was originally developed by the USAF, and has since been significantly upgraded and adapted to meet Army, Navy-Marine, and Coast Guard applications (McGrath, 2003). This mission planning tool anticipates and exploits the weather on the battlefield, thus optimizing attack effectiveness while minimizing threat exposure (Goroch, 3). Weather, target and sortie parameters (the latter two coming from information provided by war fighter/customer) are input by the meteorologist into this interactive software program, thus allowing for numerous target analyses, from maximum detection range to thermal cross-over, to be equated and disseminated in a user-friendly graphical or text format. Of concern, is how well this TAWS output verifies compared to observed surface and aircraft meteorological data especially in a scenario when weather is a major factor on the battlefield (i.e. causing degradation to weapons systems).

The Winter 2004 Operational Meteorology, MR3570, class provided a unique opportunity to receive data collected from both ship (surface target) and aircraft (sortie vehicle). The Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) provided a three-hour, data collection over flight while the Research Vessel (R/V) POINT SUR was trolling over the Monterey Bay on the afternoon of 02 February 2004. In this paper, one area of comparison is explored: the difference in TAWS derived Slant

Range Detection with that of observed Detection Ranges by members of the sortie vehicle (aircraft) over several altitudes and attack headings. The Slant Range Detection parameter is of great importance to the war fighter, primarily pilots, in that it tells the war fighter at what distance he/she will be able to have visual or lock-on capability with their weapon system of choice, of the target in interest. There is an enormous tactical significance if this Slant Range Detection is incorrect. One, it could cause the pilot to mistakenly lock on to the wrong target. Two, it could force the pilot to travel deeper into enemy territory than the mission planned before being able to discern the target at hand, thus putting themselves in greater danger from enemy fire. Three, it could scrub the mission altogether, wasting precious money, time and manpower. Clearly, characterizing and understanding these differences are critical in providing a more accurate tactical decision aid for that war fighter.

2. Data and Methods

Meteorological and oceanographic observational data of interest was collected during the oceanographic cruise on the R/V POINT SUR during the day of 02 February 2004. Of note, TAWS requests weather data up to 18 hours before Time over Target (ToT) and up to 6 hours after ToT, thus the reason why the data set is slightly larger than the actual mission time. Additionally, in-situ meteorological and remotely- sensed surface oceanographic data were collected on the afternoon of 02 February 2004 by the UV-18A "Twin Otter" aircraft from the CIRPAS facility based out of Marina, CA. Data of interest from the surface in this study consisted of wind direction, wind speed, latitude, longitude, time, air temperature, relative humidity, pressure, sea surface temperature and solar radiance. Data of interest from the flight level (FL) in this study consisted of latitude, longitude, time, air temperature, relative humidity, mixing ratio, heading and altitude. Likewise, on the aircraft, maximum detection ranges were determined by the two pilots and myself. As the "Twin Otter" would travel away from the ship, I determined at what time the ship was no longer visible to me. This was done through a convex window (See Figure 1), allowing me to view over a 180º azimuth angle which provided unobstructed sight past the fuselage of the aircraft. As the aircraft approached the ship, the pilots would determine at what time the ship came into visible range. At these critical times an on-screen display with the R/V Point Sur's exact coordinates would give us the precise distance we were from the ship. This process occurred a total of 14 times (8 in the westerly direction, 6 in the southwesterly) at three altitudes (100ft, 500ft, & 1000ft). With altitudes from only 100-1000ft, the on-screen display distances were assumed to be Slant Range.

Ship-collected measurements were collected approximately every 20 seconds. The aircraft measurements were recorded digitally by the "Twin Otter" every second. The area of study, where over flight's of the R/V POINT SUR occurred, encompassed most of the Monterey Bay area, with all flight restricted to over-water locales. The R/V POINT SUR did not travel more than 1.0 miles from its original location, staying 1-2 miles just off-shore of the town of Marina, CA. The "Twin Otter's" path of flight made a "V-like" shape about the R/V POINT SUR, with the ship located at the apex of the "V", ranging in distance from 0-25 nautical miles (nm) away from the ship at any given time during the time of concern (See Figure 2).

Slant Range Detection Comparison

To accomplish the task of comparing TAWS Slant Range Detection to the aforementioned observed Slant Range Detection values, numerous parameters had to be input into the TAWS program. TAWS breaks these input parameters into three primary categories: Target/Background Properties (See Figure 3), Sortie Properties (See Figure 4), & Meteorological Data (See Figure 5).

A. Target Background Properties

In this section we locate and describe the target (R/V Point Sur in our observation) as well as identify the physical properties of the background around the target. First, the exact position was determined by finding the mean location during the course of the exercise, in which case was found to be 36º 45'N, 121º 54'W. Next, define the target, it would have been optimal for TAWS to have a 135 ft, steel, white vessel in its database. However, it didn't. Therefore, a compromise was made to find the reflectively closest related target possible. This ended up being a 45 ft, fiberglass, white sailboat. Every other vessel was darker in color, thus, its reflectivity differences were much too different, causing abnormally low detection ranges. Also of importance, in reference to the target, were its heading, operating state and speed. An optimal heading of 315º was given to maximize the boats optical length, seeing as it was much shorter than the actual vessel. Operating state relates more to IR sensors because of heat signatures, but "on/exercised" was entered and an average speed of 1 kt was input. Only one background property was entered, which was turbid water and the aerosol type ("albedo" in TAWS) was input as ocean, with a medium clutter, where clutter is a function of amount of aerosol around the target.

B. Sortie Properties

Here, the attacking vehicle information is input. In this case, a UV-18A “Twin Otter” would have provided for optimal comparison. However, this is not thought of as a typical attack vehicle, thus not in the TAWS database. Therefore, an OA-10A, Light Grey, Thunderbolt was chosen because of its low flying capability, light color and multitude of weapon sensor capabilities. Altitude and sensor viewing direction were entered with variable coefficients. Refueling information is negligible. This section also requires a date and time stamp for ToT. Multiple ToT’s were input, as shown later. This is where the program gets all of its illumination data, of utmost importance to a visual and/or NIR sensor.

C. Meteorological Data

This in-depth section takes into account numerous surface and upper atmospheric weather parameters. As you can see on Figure 6, TAWS requests 24 hours worth of data, about 18 hours before ToT and 6 hours after ToT. This is done primarily to account for IR sensors that deal with heat budget and varying temperature effects on targets and their respective backgrounds over time. An accurate past weather input is of minimal importance to our visible eye sensor as well as the Vis/NIR TV sensor. Therefore, most of the effort was focused on the hours around the exercise. The surface values entered for the timeframe of our exercise were taken from the R/V Point Sur. Precipitation type and visibility were the only surface parameters that had to be interpolated from local radar and nearby METAR observations. However, visibility reduction looked to be minimal by the time the exercise began with only 1 stray shower passing overhead during that timeframe and a rapid reduction in visible aerosols just above the ocean surface as time progressed. Cloud information was determined by in-situ observations by myself and verified by local METAR observations. Clouds are a critical parameter for Vis/NIR sensors due to their ability to reduce incoming solar radiation and also cast shadows over targets.

3. Results and Discussion

In its basic form, visibility is directly proportional to incoming solar radiation, while inversely proportional to liquid water content, relative humidity & mixing ratio (note: there are other variables of lesser magnitude). As you can see in Figure 7, incoming solar radiation to the surface increases with time and surface relative humidity decreases with time (See Figure 8). Both of these graphs are time series of R/V POINT SUR data and would lead us to hypothesize that during the progression of the time in interest there will be an increase in Slant Range Detection. In fact, there was a general trend of higher Slant Range Detection for both observed (See Figure 9) and TAWS derived Slant Ranges as time progressed. However, before comparing the two sets of data, they must each be separated into 2 sections, Westerly heading (See Figure 10) and Southwesterly heading (See Figure 11). These values are automatically separated in TAWS, because calculations result in slight differences, due to illumination and target properties. A numerical comparison of observed vs. TAWS derived Slant Ranges shows that observed values are about 72.5% that of TAWS derived values. In a Westerly heading this trend continues throughout the entire timeframe (8 observations, See Figure 10), however, there is a greater slope towards like values in the Southwesterly heading as time progresses (See Figure 11). A few Slant Range vs. azimuth angle plots (See Figures 12-

14) comparing the same data at a single point-in-time show similar results. Of note in Figure 13, are two TAWS derived Slant Range radar plots. The plot with a typically shorter Slant Range is with no direct sunlight added to the target, while the larger Slant Range plot does take into account direct sunlight, thus illuminating the target better by enhanced reflectivity. This occurred at 2220z because, as you can see from Figure 7, incoming solar radiation to the surface becomes much greater as the front has passed and clouds start to break up. As you can see, this has the greatest change in the SW corridor, because that is where the sun location is at late in the afternoon, reflecting off of the ship which has a perpendicular heading and the reflected light comes right back to the aircraft, located in that SW corridor. The least change is to the NE, where you wouldn't see any enhanced reflectivity on NE side of the ship because you would be looking at the shadowed part of the ship thanks to its heading and the suns location in the sky.

If there had been no significant weather issues, there would have been a decrease of incoming solar radiation during the exercise time (See Figure 15), thus shorter Slant Ranges as time progressed. However, this did not happen, telling us that there were weather effects early and that they were accounted for in TAWS and evident in observed data. Furthermore, the slope trend of each Slant Range graph was fairly similar, a positive result in comparing model data with observed data.

4. Conclusions

The comparison of TAWS derived Slant Range vs. observed Slant Range resulted in a fairly significant numerical difference (derived data was on the order of about 3.5 nm longer per leg), however, a similarly strong increasing trend during our exercise time was evident in both data sets. This information, with the knowledge that had weather not been an impact, Slant Ranges would have decreased, shows that both data sets are proportional and that the TAWS derived data is representative even in a daytime environment, which is not what the program is specifically designed for. That said, the observed Slant Range data set is small, has only two view directions, and is not 100% reliable in that determining when visual is lost is a very difficult and subjective process, especially from a convex window. As for the TAWS output, it had near perfect weather inputs (hind-sight forecasting is always a bonus). However, its target was optically quite different, and the sensor chosen was a TV sensor, which sees in the spectrum of visible and NIR wavelengths, rather than just the visible range that our eyes were detecting. These two large assumptions could be the result for even more comparison difference or possibly a better comparison. It would foolish to speculate and the answer will only come when the TAWS program has input possibilities that better match observed targets & sensors.

5. Recommendations for Future Studies

First and foremost, a study with fewer assumptions in TAWS would greatly improve reliability. This could come in the form of the aviator using forward looking Infrared (FLIR), which is a common sensor that TAWS has many variations of and pilots use frequently on nighttime bombing missions. Another nighttime case could be to use night vision goggles (NVG's). NVG's are also a commonly used sensor in TAWS and its applications are wide-spread. Another way eliminate assumptions in TAWS would be to use an exact target that is in the TAWS database. A target along the coastline, say, the

Moss Landing Power Plant, or a radio tower would suffice. However, do watch out for airspace clearance. The reason why we only conducted westerly and southwesterly ranges out over the bay was because we had to stay a certain distance away from the Monterey Airport so as to not disturb incoming and outgoing traffic. Lastly, if the visible sensor is a must, than a study using Electro-Optical Signal Transmission and Ranging (EOSTAR) rather than TAWS would be a possibility. This program describes the atmospheric effects on long-range, optical imaging at low levels over the sea surface (Davidson, 2004). Had I known more about the program earlier in the quarter I would have tried to use it, seeing as its mission is almost identical to that of this project.

References

McGrath, C. 2003: TAWS Improvements for Over-Water Targets. *SPAWAR*

Goroch, A. 2004: Tactical Decision Aids. *NRL Monterey*. Slides 1-79

Davidson, K. 2004: EOSTAR Lab Exercise. *NPS*.

CIRPAS “Twin Otter” Plane and various highlighted instrumentation

Figure 1

MR3570 “Twin Otter” Plane Tracks, every 30s, 2115z-2305z, 2 Feb 04

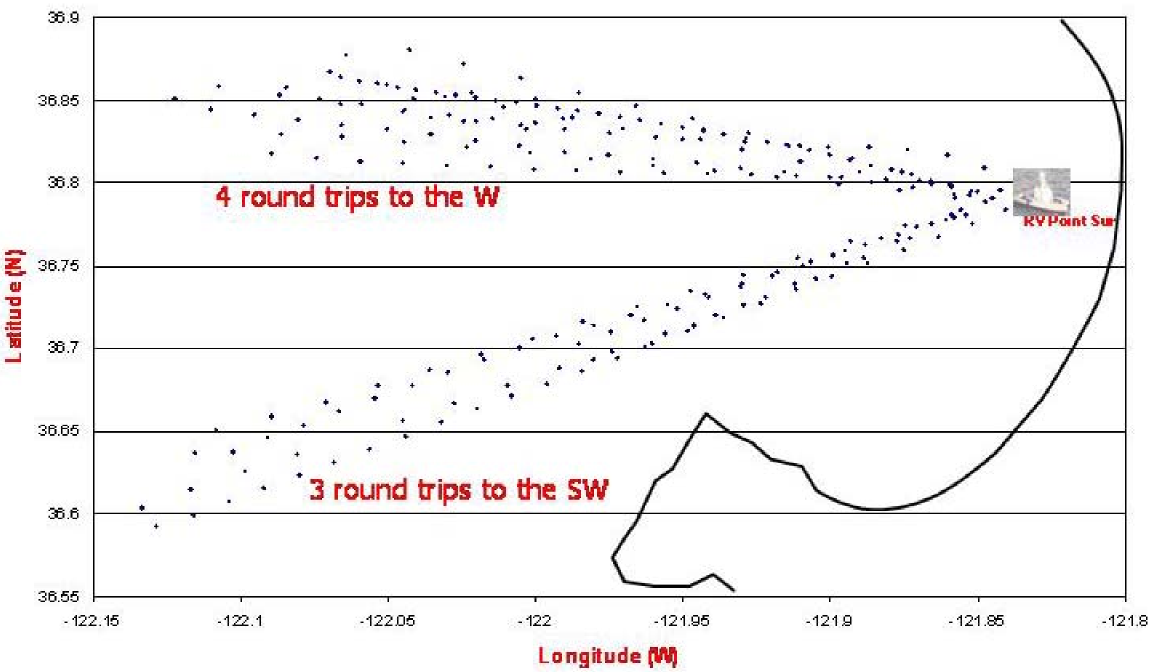

Figure 2

TAWS Target/Background Properties

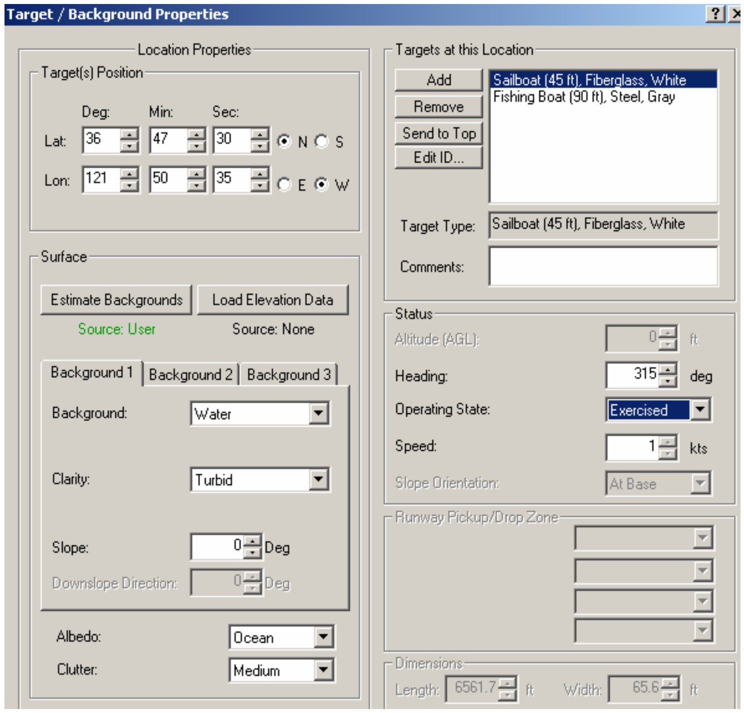

Figure 3

TAWS Sortie Properties

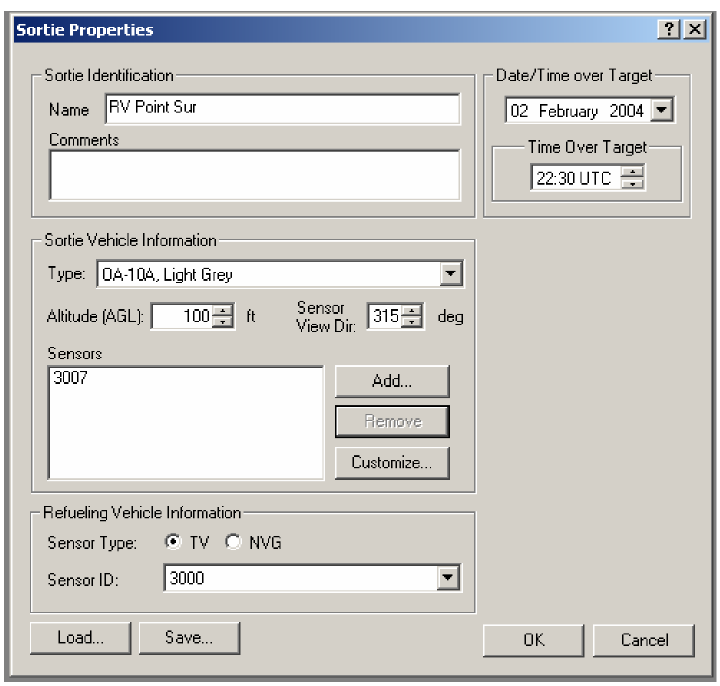

Figure 4

TAWS Meteorological Data

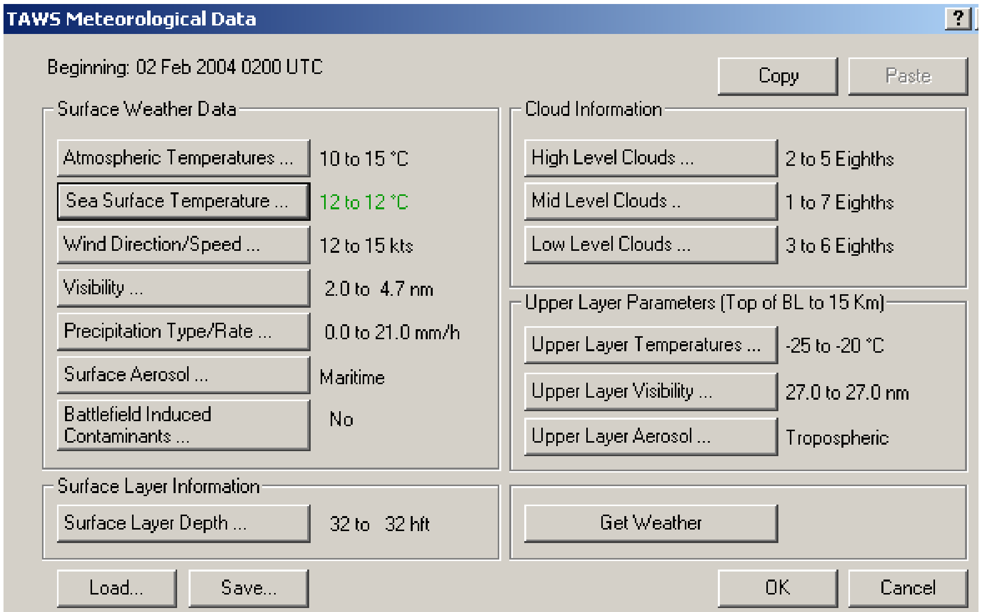

Figure 5

TAWS Meteorological Data – Example of its Temporal Resolution

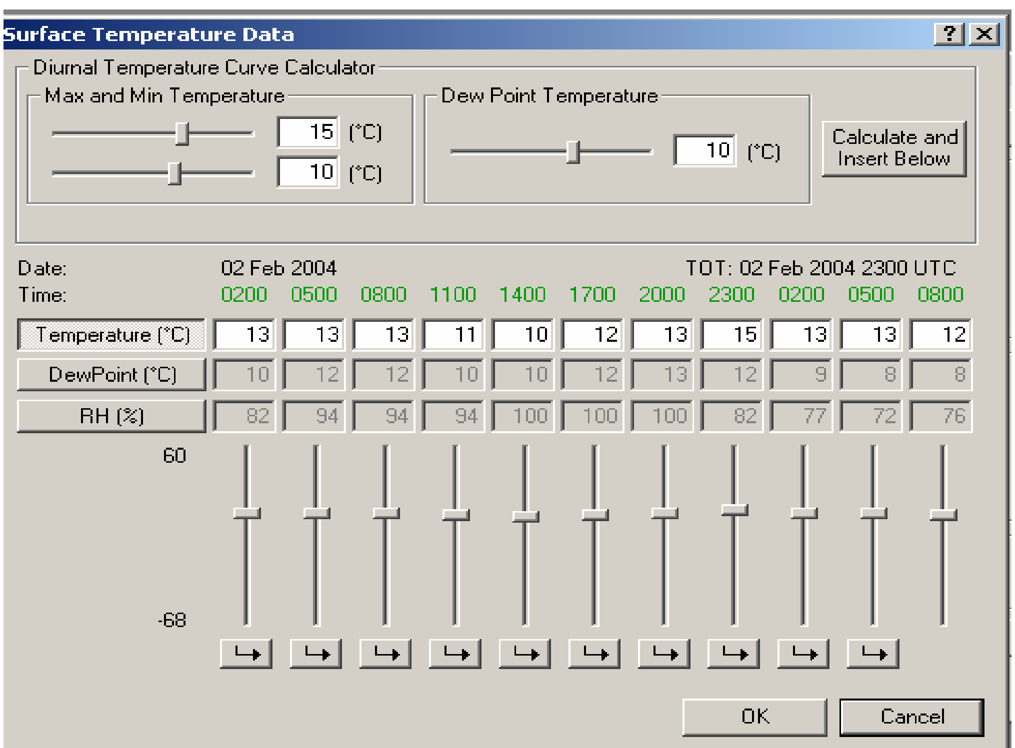

Figure 6

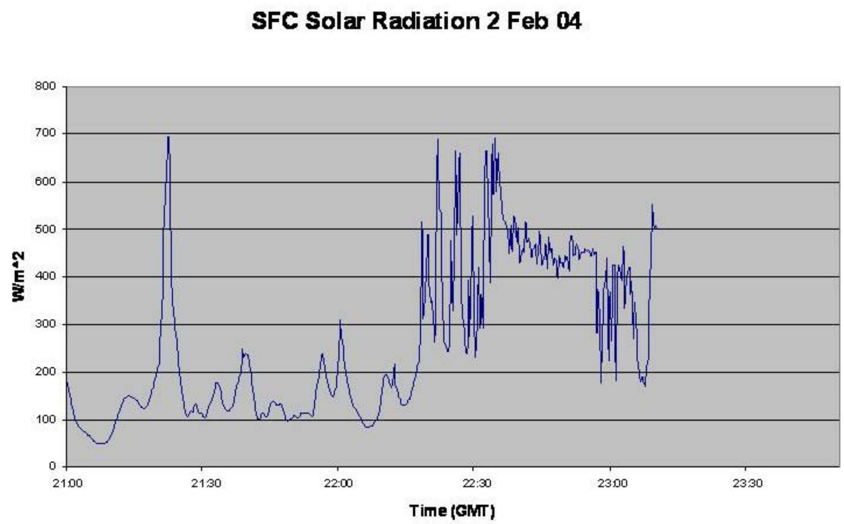

Figure 7

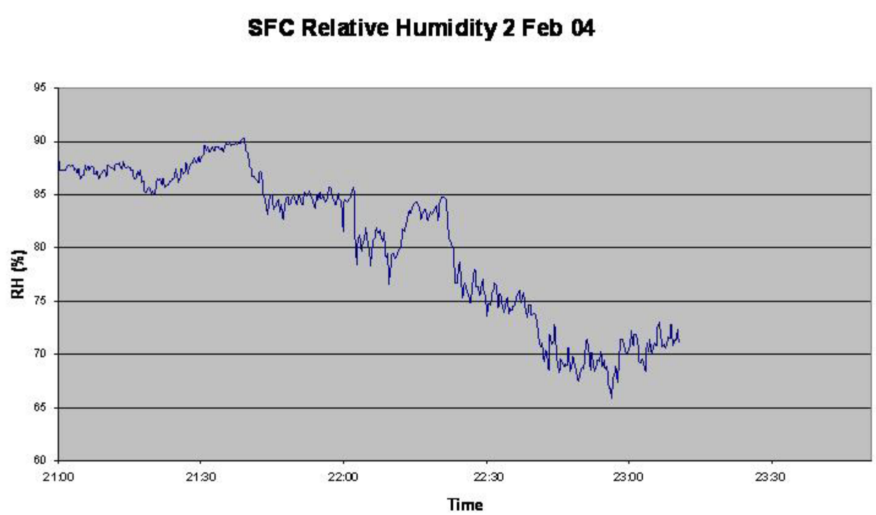

Figure 8

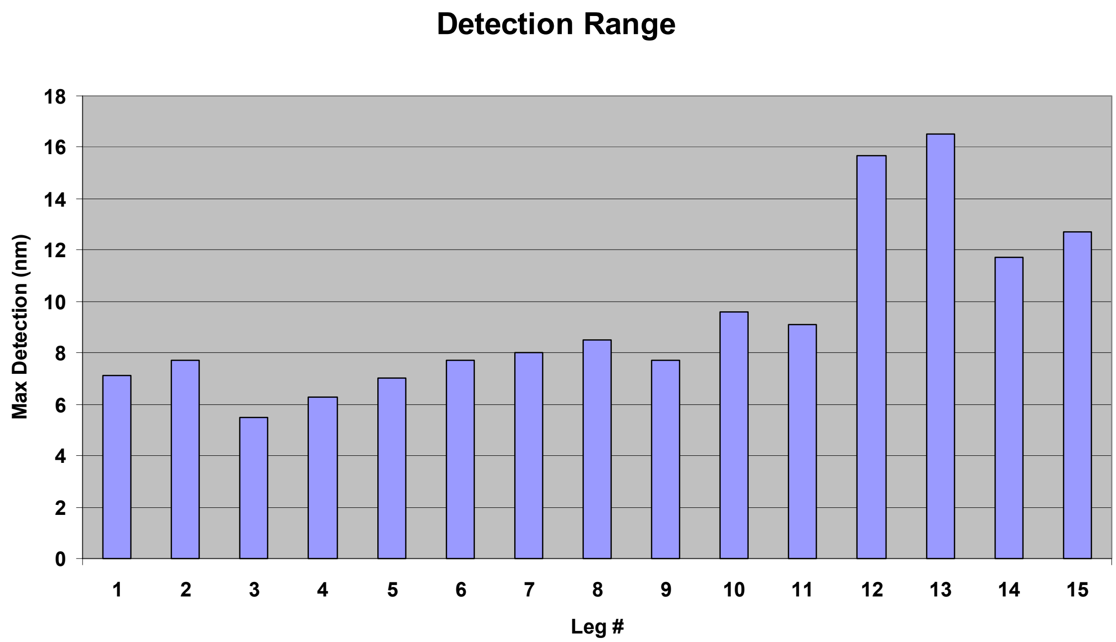

Figure 9

Comparison of TAWS derived & observed Slant Range vs. Time (W'rly Heading)

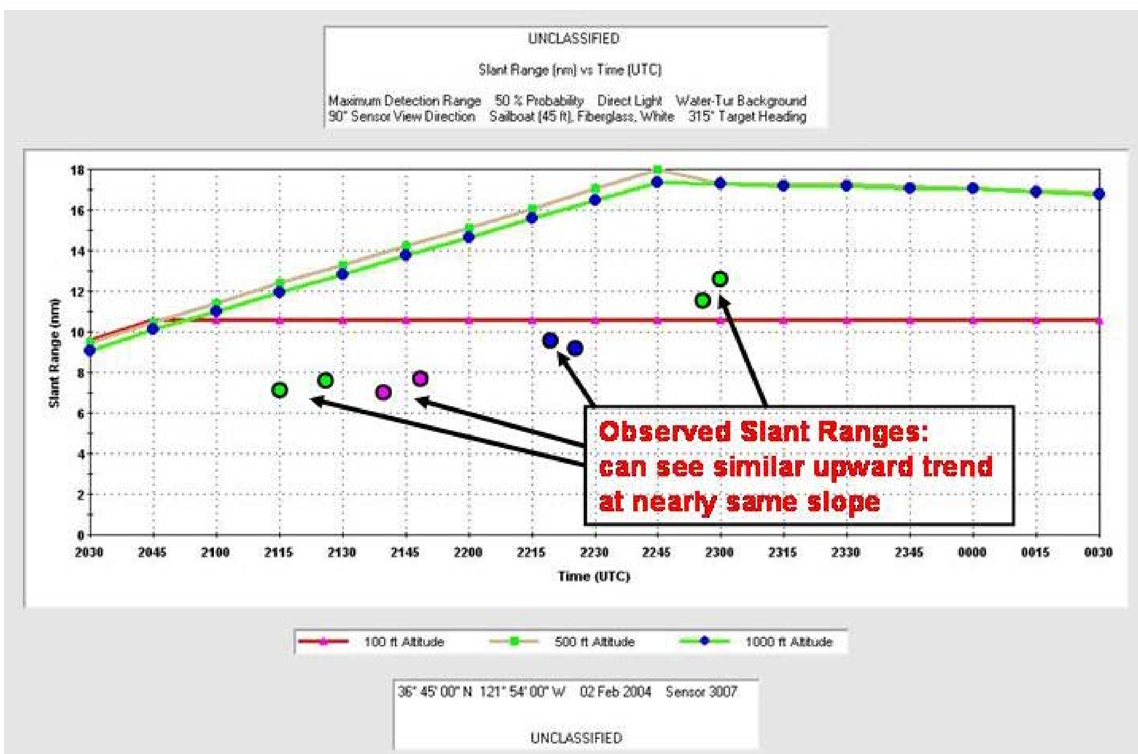

Figure 10

Comparison of TAWS derived & observed Slant Range vs. Time (SW'rly Heading)

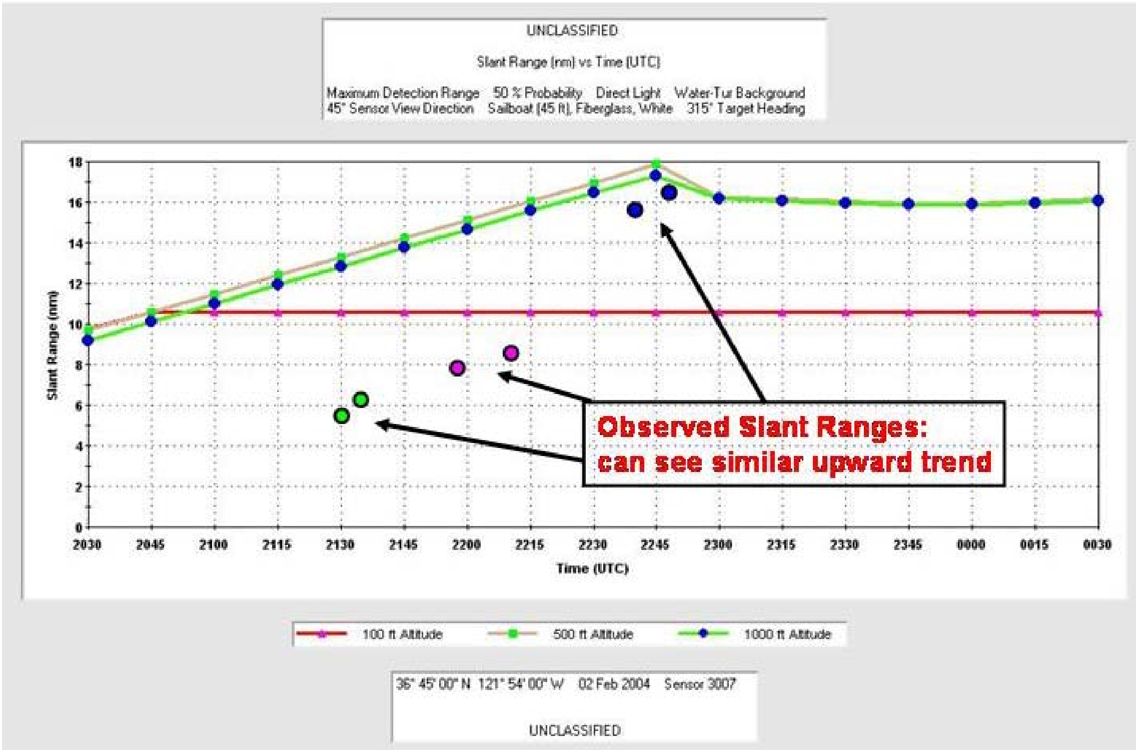

Figure 11

Comparison of TAWS derived & observed Slant Range vs. Azimuth Angle (2120z)

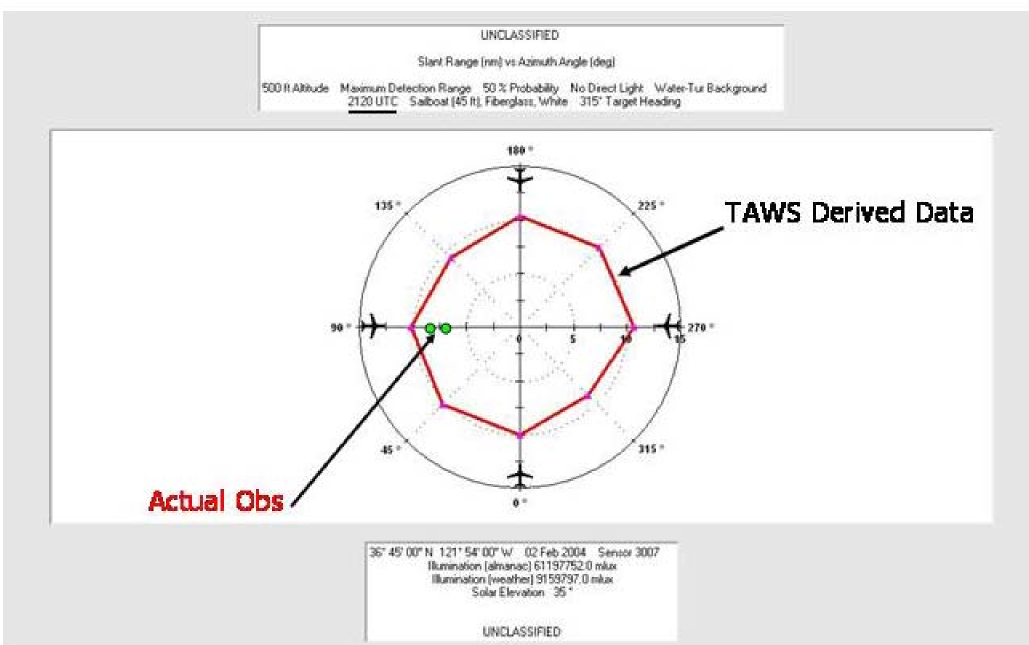

Figure 12

Comparison of TAWS derived & observed Slant Range vs. Azimuth Angle (2220z)

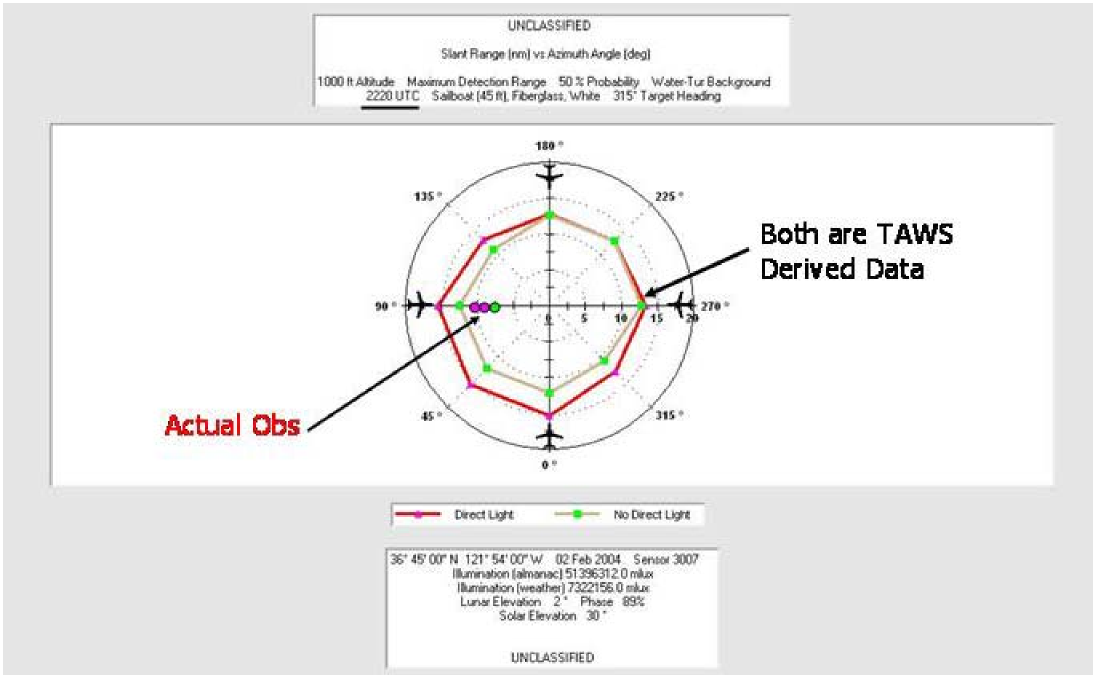

Figure 13

Comparison of TAWS derived & observed Slant Range vs. Azimuth Angle (2245z)

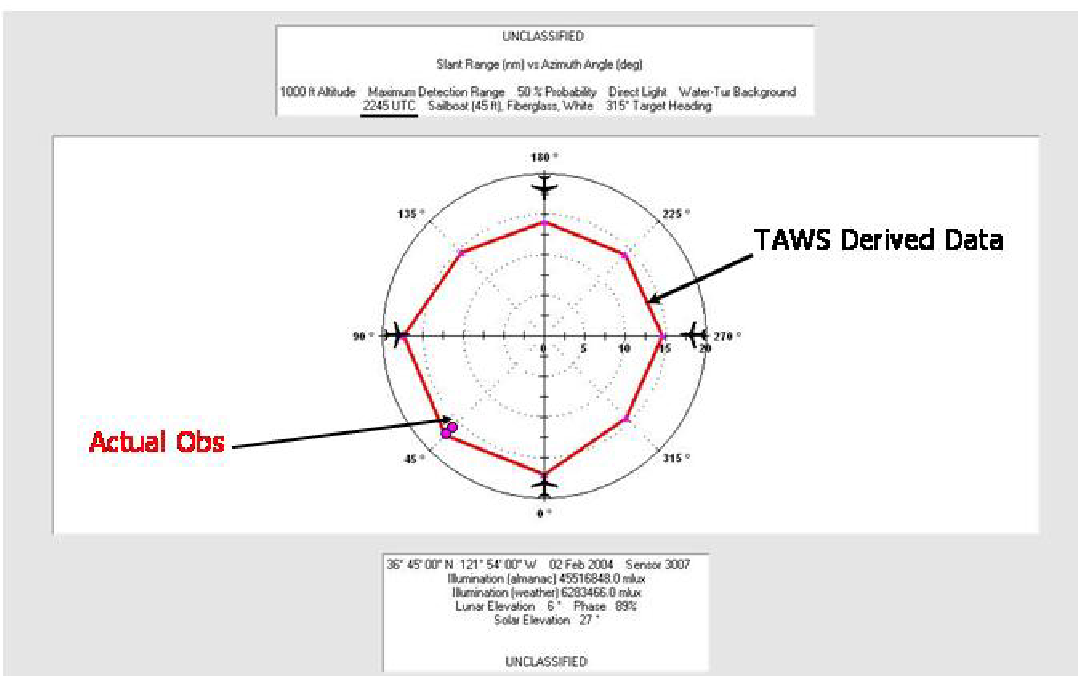

Figure 14

Solar Radiance had there been NO Significant Weather Effects

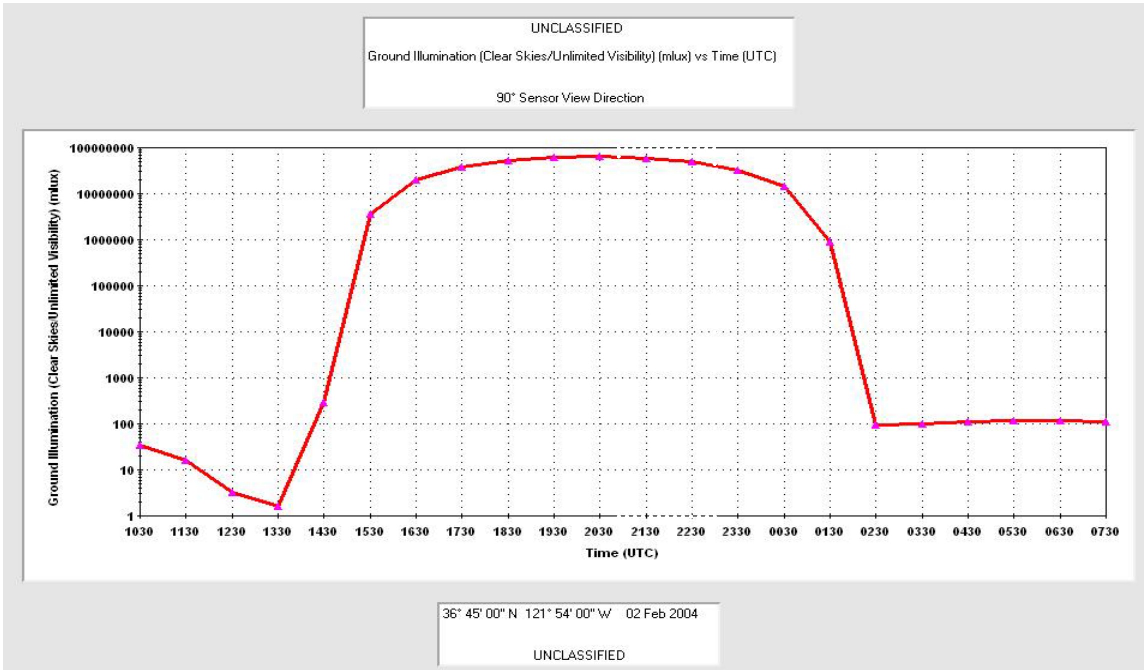

Figure 15